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MARS PATHFINDER SCIENCE INVESTIGATIONS AND OBJECTIVES[1]

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Abstract

Mars Pathfinder, one of the first Discovery class missions (quick, low-cost projects with focused science objectives), will land a single vehicle with a microrover and several instruments on the surface of Mars in 1997. Pathfinder's primary objective is to demonstrate an inexpensive system for cruise, entry, descent, and landing on Mars. Additional objectives include the deployment and operation of various science instruments: a stereoscopic imager with filters on a pop up mast, an alpha proton x-ray spectrometer (APXS), and an atmospheric structure instrument/meteorology package. The surface imaging system will reveal the geologic processes and surface-atmosphere interactions at a scale currently known only at the two Viking landing sites. The alpha proton x-ray spectrometer and the spectral filters on the imaging system will determine the elemental composition and mineralogy of surface materials, which can be used to address questions concerning the composition of the crust, its differentiation and the development of weathering products. These investigations will represent a calibration point ("ground truth") for orbital remote sensing observations. In addition, a series of small magnets and a reference test chart will determine the magnetic component of the martian dust and any deposition of airborne dust over time. The atmospheric structure instrument will determine a pressure, temperature and density profile of the atmosphere (with respect to altitude) during entry and descent.

Diurnal variations of the atmospheric boundary layer will be characterized by regular surface meteorology measurements (pressure, temperature, atmospheric opacity, and wind speed and direction). In addition, the imager will determine dust particle size and shape and water vapor abundance from sky and solar spectral observations,

Introduction

The Mars Pathfinder Project received a new start in October 1993 as the next mission in NASA's long term Mars exploration program. The mission involves landing a single vehicle on the surface of Mars in 1997. The project is required to be low cost ($ 150M development cost cap, excluding launch vehicle and mission operations), have a fast schedule (less than 3 years development period), and achieve a set of significant, but focused engineering, science, and technology objectives. The primary objective is to demonstrate a low cost cruise, entry, descent, and landing system required to place a payload on the martian surface in a safe, operational configuration. Additional objectives include the deployment and operation of various science instruments and a microrover (an additional $22M development). Pathfinder paves the way for a cost effective implementation of future Mars lander missions.

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1 =Thc work described in this paper was performed at the Jet Propulsion Laboratory, California Institute of

This paper attempts to convey the present status of the scientific aspects of the Mars Pathfinder mission, First, the flight system and mission are briefly described. A general description of the scientific objectives and investigations afforded by Pathfinder is followed by a description of each science instrument.

Finally, the process for selecting a landing site on Mars is described along with the site that Mars Pathfinder will land.

Mission and Spacecraft Overview

The Pathfinder flight system consists of three major elements (Fig. 1): the cruise stage, the deceleration subsystems, and the lander (containing the rover and science instruments). The current spacecraft launch mass is approximately 710 kg, including 25 kg of payload (science instruments, rover, and rover support equipment).

Pathfinder is launched in the December 1996 - January 1997 time period on a Type 1 Earth-Mars transfer trajectory, The primary activities during the 6-7 month cruise phase include periodic attitude control maneuvers required to remain Earth pointed, and four trajectory correction maneuvers needed to insure accurate arrival targeting at Mars. The cruise stage is jettisoned prior to entry into the Martian atmosphere. Cruise stage hardware consists of a solar array and additional related power equipment, a medium gain antenna, propulsion thrusters, propulsion valves and tanks, and attitude determination sensors.

At Mars arrival on July 4, 1997, the spacecraft enters the atmosphere directly from the hyperbolic approach trajectory. The lander velocity is reduced through the sequential 'application of aerodynamic braking by a Viking heritage aeroshell and disk-gap-band parachute, propulsive deceleration using small solid tractor

The lander is a tetrahedron shaped structure containing the science instruments, rover, and all electronic and mechanical devices required to operate on the surface of Mars. The tetrahedron consists of four similarly shaped triangular panels. All lander equipment except the solar arrays and rover are attached to a single center panel. The other three panels are attached to the edges of the center panel using actuators that are used to right the lander after touchdown. All thermally sensitive electronics are contained in an insulated enclosure on the center panel. Specific hardware components inside this enclosure include a high performance central computer, a Cassini heritage transponder, a solid state power amplifier for telecommunications, and a high capacity rechargeable battery. Hardware outside the thermal enclosure includes a steerable high gain antenna capable of approximately 5.5 kbps into a 70 m Deep Space

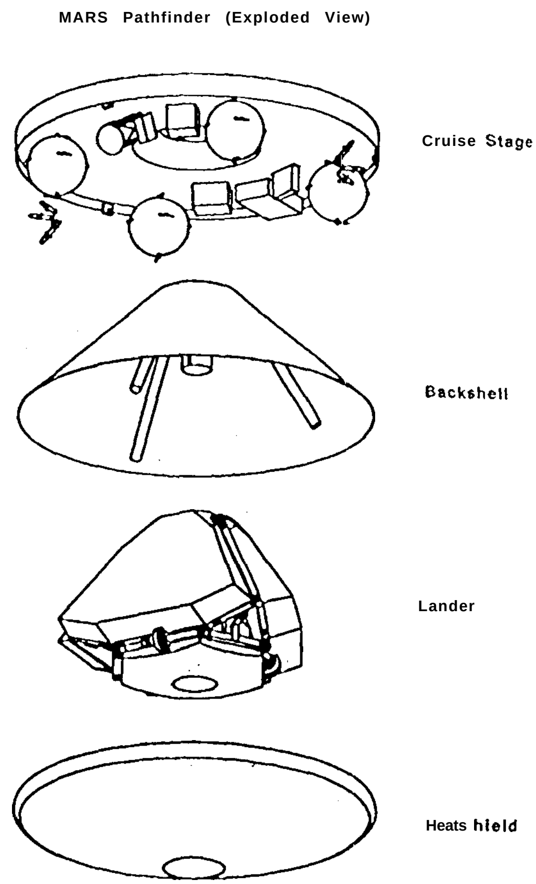

Fig 1. Exploded view of Mars Pathfinder flight system, showing back-pack-style cruise stage, backcover with three solid rockets, tetrahedron-shaped lander, and aeroshell.

rockets, and airbags to null the remaining vertical and horizontal velocity components at surface impact. The lander is lowered beneath the backcover on an incremental tether, with a radar altimeter used to trigger rocket firing and airbag inflation.

Network antenna and solar arrays capable of providing enough power to transmit for at least 2 hours per sol and maintain 128 MB of dynamic memory through the night. All engineering and science data obtained during the entry, descent, and landing phase are recorded for playback at the initiation of lander surface operations. The lander is capable of surviving for a minimum of 30 SOIS, with a likely lifetime of up to a year.

The rover on Mars Pathfinder is a small (1 O kg), six wheel drive rocker bogie design vehicle, which is 65 cm long by 48 cm wide by 32 cm high. The rocker bogie chassis has demonstrated remarkable mobility, including the ability to climb obstacles one wheel diameter in height and the capability of turning in place. The vehicle communicates through the lander via a UHF antenna link and operates almost entirely within view of the lander cameras, or within a few tens of meters of the lander, It is a solar powered vehicle, with a primary battery back-up, which moves at 0.4 m/min, and carries 1.5 kg of payload. The payload consists of monochrome stereo forward cameras for hazard detection and terrain imaging and a single rear camera. On the rear of the vehicle is the alpha proton x-ray spectrometer (APXS) mounted on a deployment device that enables placing the APXS sensor head up against both rocks and the soil. The rear facing camera will image the APXS measurement site with 1 mm resolution. The rover also carries two technology experiments described l ater and a variety of hazard detectiön systems for safing the vehicle. General scientific guidance for the rover is provided by an appointed Rover Scientist, Henry Moore (U. S. Geological Survey).

The rover will also perform a number of technology experiments designed to provide information that will improve future planetary rovers. These experiments include: terrain geometry reconstruction from lander/rover imagery; basic soil mechanics by imaging wheel tracks and wheel sinkage; dead reckoning sensor performance and path reconstruction/recovery; logging/trending of vehicle data; rover thermal characterization; rover vision sensor performance; UHF link effectiveness; material abrasion by sensing abrasion of different thicknesses of paint on a rover wheel;, and material adherence by measuring dust accumulation on a reference solar cell with a removable cover and by directly measuring the mass of the accumulated dust on a quartz crystal microbalance.

Mars Pathfinder Science Objectives and Investigations

The science payload chosen for Mars Pathfinder includes an imaging system, an elemental composition instrument and an atmospheric structure instrument/meteorology package. (Fig, 2) These instruments, used in conjunction with selected engineering subsystems aboard both the lander and rover vehicles, provide the opportunity for a number of scientific investigations. The scientific objectives and investigations afforded by Pathfinder include: surface morphology and geology at meter scale, elemental composition and mineralogy of surface materials and a variety of atmospheric science investigations.

The surface imaging system will reveal martian geologic processes and surface-atmosphere interactions at a scale currently known only at the two Viking landing sites. It will observe the rock distribution, surface slopes and general physiography in order to understand the geological processes that created the surface. This will be accomplished by panoramic stereo imaging at various times of the day as well as before and after the imager deploys on its pop-up mast. Images will be calibrated by observing a flat field target near the imager head and shadowed and illuminated portions of a reference or calibration target. In addition, observations over the life of the mission will allow assessment of any changes in the scene over time that might be attributable to frost, dust or sand deposition or erosion or other surface-atmosphere interactions. The rover will also take close-up images of the terrain during its traverses. A basic understanding of near-surface stratigraphy and soil mechanics will be obtained by imaging (from both rover and lander) rover tracks, holes dug by rover wheels, and any surface divots left by the spacecraft landing.

The APXS and the visible to near infrared (0.4 to 1 micron) spectral filters (particularly sensitive to pyroxene and iron oxides) on the imaging system will determine the elemental composition and constrain the mineralogy of rocks and other surface materials, which can be used to address questions concerning the composition of the crust, its differentiation and the development of weathering products. These investigations will represent a calibration point ("ground truth") for orbital remote sensing observations. The imaging system will obtain full multispectral panoramas of the surface and any subsurface layers exposed by the rover and lander. Because the APXS is mounted on the rover it will characterize the composition of rocks and soil in the vicinity of the lander (tens of meters), which will represent a significant improvement in our knowledge over that obtained by Viking or that likely to be obtained by the Russian Mars 94 (now delayed to 1996) small stations, which deploy the APXS on single degree of freedom arms. The rover-mounted APXS sensor head on Pathfinder will also be placed in holes dug by the rover wheels and against rocks that have been abraded by a rover wheel. Multispectral images arc also planned for 3 sets of magnetic targets distributed at various points (and heights) around the spacecraft that will identify the magnetic phase of accumulated airborne dust. In addition, APXS measurement of magnetic targets in the rover ramps will determine the titanium content of the dust, which is critical for discriminating the various magnetic phases. A rear-facing imager will enable close-up images with millimeter resolution of every APXS measurement site. Between these images and auxiliary information from lander imaging spectra, it is likely that mineralogical determinations will be possible from the elemental abundances measured by the APXS.

The atmospheric structure instrument will determine a pressure, temperature and density profile of the atmosphere during entry and descent at a new location, time and season from the two Viking profiles. Measurements of pressure and temperature will bc made during descent. Redundant three-axis accelerometers will allow extraction of atmospheric pressure during entry. Diurnal variations in the atmospheric boundary layer will be characterized by regular surface meteorology measurements (pressure, temperature, atmospheric opacity, and wind). Thermocouples, mounted on a meter high mast located on a petal away from the thermal enclosure, will determine the temperature profile with altitude. A wind sensors will be placed at the top of this mast. Together with 3 or more wind socks on the mast, they will allow determination of wind speed and direction versus altitude in the boundary layer, allowing calculation of aerodynamic roughness of the surface. Regular sky and solar spectral observations will also monitor dust particle size and shape, refractive index, vertical aerosol distribution and water vapor abundance,

Mars Pathfinder Scientific instruments

Imager for Mars Pathfinder (IMP)

The Imager for Mars Pathfinder (IMP), proposed by Peter Smith of the University of Arizona was selected through a NASA Announcement of Opportunity as a Principal Investigator experiment, In addition to the camera hardware, the investigation includes a variety of spacecraft targets including radiometric calibration targets, magnetic properties targets and wind socks.

The stereoscopic imager is deployed on a jack-in-the-box pop up mast that is roughly 1.5 m above the surface (0.85 m above the lander). It includes two imaging triplets, two fold mirrors separated by 150 mm for stereo viewing, a 12-space filter wheel in each path, and a fold prism to place the images side-by-side on the CCD focal plane, which is being provided by H. Uwe Keller of the Max Planck Institut fur Aeronomie. Fused silica windows at each path entrance prevent dust intrusion. The optical triplets are an f/10 design, stopped down to f/18 with 23-mm effective focal lengths and a 14.4° field of view. The focal plane consists of a CCD mounted at the foci of two optical paths. Its image section is divided into two square frames, one for each half of the stereo pair. Each of the stereo frames has 256x256 active elements. The pixel instantaneous field of view is one milliradian. The filter wheels have 24 positions, with most filters for geologic studies (0.4- 1.1 microns, which are particularly sensitive to pyroxene and iron oxides) and stereo viewing, others for atmospheric water vapor and dust and a magnifying close-up lens. Azimuth and elevation drives provide a field of regard of 370° in azimuth and +90° to -79° in elevation, relative to lander coordinates.

A magnetic properties investigation is being provided by Jens Martin Knudsen of the Niels Bohr Institute, University of Copenhagen. A set of magnets of differing field strengths will bc mounted to a plate and attached to the lander at two different locations. Images taken over the duration of the landed mission will be used to determine the accumulation of magnetic species n the wind-blown dust. Multispectral images of these accumulations may be used to differentiate among potential mineral compositions.

The IMP investigation includes the observation of wind direction and speed, using small wind socks mounted on a boom which are being provided by Ron Greeley of Arizona State University. Calibration and reference targets mounted to the lander complete the hardware complement.

Alpha Proton X-Ray Spectrometer (APXS)

This instrument is a foreign-provided copy of an instrument design flown on the Russian Vega and Phobos missions and is planned for flight on the now delayed Russian Mars '94 and Mars '96 missions. Accordingly the instrument has extensive, applicable flight heritage.

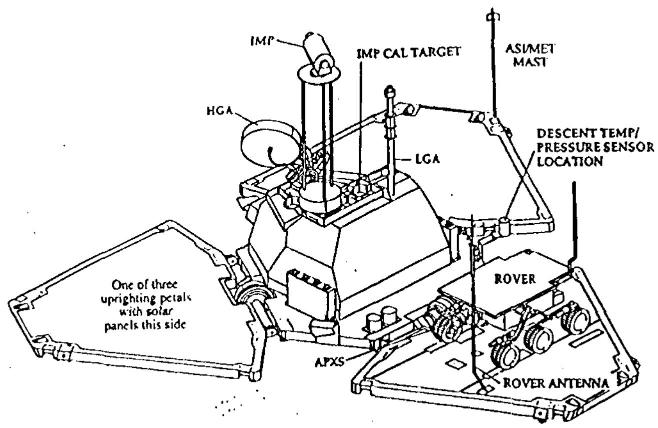

Fig 2. Perspective view of lander opened on the surface showing the location of the instruments and rover. IMP is the Imager for Mars Pathfinder. IMP Cal Target is the IMP calibration target. APXS is the alpha proton x-ray spectrometer mounted on the back of the rover. HGA and LGA are the high-gain and low-gain antennas respectively. Temperature and wind sensors for the surface meteorology experiments are mounted on the ASI/MET mast. Entry and descent pressure and temperature sensors are located in indicated triangular space between the lander panels.

The alpha and proton spectrometer portions are provided by the Max Planck Institut fur Chemie, Mainz, Germany, under the direction of Rudi Rieder, 1'.1. The x-ray spectrometer portion is provided by Thanasis Economou of the University of Chicago,

This elemental composition instrument consists of alpha particle sources and detectors for back-scattered alpha particles, protons and x-rays. The APX spectrometer will determine elemental chemistry of surface materials fOr most major elements except hydrogen and helium, The analytical process is based on three interactions of alpha particles with matter: elastic scattering of alpha particles by nuclei, alpha-proton nuclear reactions with certain light elements, and excitation of the atomic structure of atoms by alpha particles, leading to the emission of characteristic x-rays. The approach used is to expose material to a radioactive source that produces alpha particles with a known energy, and to acquire energy spectra of the alpha particles, protons and x-rays returned from the sample. Accordingly, the instrument can identify and determine the amounts of most chemical elements.

The basis of the alpha mode of the instrument is the dependence of the energy spectrum of alpha particles scattered from a surface on the composition of the surface material. The method has the best resolving power for the lighter elements.

The proton spectra for alpha particles interacting with elements with atomic numbers from 9 to 14 are very characteristic of the individual elements, reflecting the resonance nature of the nuclear interactions involved. The proton mode allows their detection and measurement.

The addition of a third detector for x-rays results in a significant extension of the accuracy and sensitivity of the instrument, particularly for the heavier, less abundant elements. Alpha sources produce characteristic x-rays for a range of elements, giving an instrument sensitivity to a tenth to a hundredth of a percent concentration levels.

The APXS sensor head is mounted external to the Rover chassis on a deployment mechanism which allows the instrument to be placed in contact with both rock and soil surfaces at a wide variety of elevations and angles, The APXS electronics are mounted within the Rover, in a temperature-controlled environment.

Atmospheric Structure Instrument / Meteorology Package (ASI/MET)

The ASI/MET is implemented as a facility experiment, developed' by JPL, to provide engineering support to the measurement of the entry descent and landing conditions and to acquire science data both before and after landing. An appointed Science Advisory Team, under the leadership of Al Sieff (Ames Research Center/San Jose State University) provides scientific guidance to the JPL instrument team.

Data acquired during the entry and descent of the lander permits the reconstruction of profiles of atmospheric density, temperature and pressure from altitudes in excess of 100 km to the surface.

The accelerometer portion of the experiment is provided by the Attitude and Information Management subsystem (AIM). It consists of redundant x-, y- and z-axis sensors. Three gain states are provided to cover the wide dynamic range from the micro-g accelerations experienced upon entering the atmosphere to the peak deceleration experienced during entry into the atmosphere.

The ASI/MET instrument hardware consists of a set of temperature, pressure and wind sensors mounted on the lander and an electronics board for operating the sensors and digitizing their outputs. Temperature, pressure, and wind sensors are located aboard the lander at locations suitable for measuring descent and post-landed conditions.

Pressure and temperature sensors are sampled twice per second during entry and descent. Temperature, pressure, wind speed and direction are sampled hourly throughout the landed mission at multiple heights above the local surface,

Mars Pathfinder Landing Site

Engineering Constraints

A variety of engineering considerations constrain the location of potential landing sites for Pathfinder. The site must be between O°N and 30°N so that the lander and rover solar arrays can generate the maximum possible power (the sub-solar latitude on July 4, 1997 is 15°N) and to facilitate communication with Earth (the sub-Earth latitude at this time is 25°N). The reference altitude of the site must be below O km so that the descent parachute has sufficient time to open and slow the lander to the correct terminal velocity. Landing will occur within a 100 km by 200 km ellipse along a N74E axis around the targeted site due to navigational uncertainties during cruise and atmospheric entry.

Landing Site Workshop

The short time frame required for the development and launch of Pathfinder, requires quick decisions where possible to keep costs at a minimum. In keeping with this philosophy, and the unfortunate circumstance that no new spacecraft will be visiting and returning data from Mars before Pathfinder lands, the decision was made to choose the landing site early in the development of the spacecraft/project. In addition, because Mars Pathfinder is the next mission to Mars and the next landing on the red planet (since Viking -20 years ago), the choice of a landing site carries an importance that exceeds the immediate project. With these considerations in mind it was decided to hold an open workshop on potential landing sites that solicited participation by the entire Mars scientific community. The "Mars Pathfinder landing Site Workshop" was held April 18-19, 1994 at the Lunar and Planetary Institute in Houston, Texas.[2] Over 60 interested scientists and engineers from around the United States and Europe gathered to discuss potential landing sites on Mars. Presentations included a description of the mission, spacecraft and instruments, general landing site perspectives from a variety of disciplines, data pertaining to landing site safety, and over 20 proposed individual landing sites.

A variety of general observations from the workshop and discussions were very successful in helping to choose a landing site and are discussed below. First, there was no. unanimous first choice landing site for all participants. In other words, there was no "dinosaur bone site" on Mars that all felt was so compelling that Pathfinder had to go there. Second, virtually all types of landing sites proposed are available within the preferred constraints of being within 5 degrees of 15 degrees north latitude (for maximum solar power) and below O ktn elevation.

Three general types of landing sites were proposed by participants of the workshop:

1) *"Grab Bag" Site* - a place such as the mouth of a large catastrophic outflow channel in which a wide variety of rocks are potentially available and within reach of the rover. Even though the exact provenance of the samples would not be known, the potential for sampling a large diversity of martian rocks in a small area could reveal a lot about Mars overall. Data from subsequent orbital remote sensing missions would then be used to infer the provenance for the "ground truth" samples studied by Pathfinder.

2) *Large Uniform Site* (at Viking resolution).

a) *Large Uniform Site of Unknown Rock Type.* The site appears uniform at Viking resolution, but the interpretation of rock type or composition of the unit is uncertain. Landing at the site would allow determination of the rock type that makes up the unit. Several of these sites were presented and received strong support at the workshop.

b) *Large Uniform Site of Suspected or Known Composition,* such as a lava flow. landing at such a site would confirm the rock type and measure something about it that was important (e.g., iron and magnesium content of a basalt).

In general, it seemed that many of the attendees and the various science disciplines represented were supportive of a "grab bag" site that holds the prospect of learning the most about what Mars is made of. These sites are all located where catastrophic flood channels debouch into Chryse Planitia and have cut through a variety of ancient Noachian crustal units as well as the Hesperian Ridged Plains and a variety of other units. The potential of analyzing a variety of rocks that likely makeup 2/3 of the crust of the planet, even without knowing their provenance exactly, is an exciting prospect for the next landed mission to Mars. What makes this type of site potentially more interesting than simply landing in the highlands themselves is the possibility of sampling more different highlands materials than might be accessible otherwise. These sites are likely similar to the Viking 1 landing site: both rocky and dusty.

The other area of interest to a variety of scientists was the Cerberus region. This area holds the potential of sampling a widespread low-albedo surface eolian unit, interpreted in this area to be mafic sand. In this region, a variety of different crustal units are available, including what may be unweathered highlands material. This area will likely look different from the Viking landing sites, being relatively rock-poor and dust free. Going to sample this dark eolian unit is equivalent to going to a large uniform site of unknown origin.

A smaller group of scientists wanted to go to sediments; unfortunately uniquely identifying sediments from Viking images is difficult and it would be difficult to be sure that the desired sediments would be within reach of the rover after landing. In addition, Pathfinder's instruments arc much better suited to determining the mineralogy of rock rather than soil,

In general, few scientists present were very excited about landing at a large uniform site of suspected known composition, given that this effectively involves going to a basalt flow (one of the few rock types on Mars identifiable from orbit). This was underscored by the widely accepted hypothesis that we already have samples of young basalts from Mars in the form of the SNC meteorites. Going to Mars to confirm that the SNC meteorites are, in fact, from Mars did not get much support at the workshop. Taken one step farther, this led many to conclude that sampling ancient crust is potentially more compelling than trying to sample other materials, given that the highlands represent most of what Mars is made of and likely record first order processes such as planetary differentiation and early climatic conditions, In addition, we have virtually no knowledge about what a highland surface looks like, or what processes dominated in its formation (topics that could be addressed by a Pathfinder landing).

Landing Site Selection Process

Given these general guidelines, the following decisions were made to narrow down the selection. First, all the sites proposed at the Landing Site Workshop were plotted on the 1: 15M geologic maps. All sites above O km elevation or outside of 10-20 degrees north latitude (i.e., 5 degrees around the sub-solar latitude of 15 degrees north, required for maximum solar power generation) were omitted. If a proposed site fell outside this latitude band, it was moved within the band if the same general geologic unit was available. In addition, a few other sites that are within the engineering constraints and have preferred science attributes expressed at the workshop were added. (Examples arc ridged plains and highland sites with low-albedo eolian cover), All sites within radar stealth regions or with very low thermal inertia (interpreted to be very low density dust of considerable thickness with little or no bearing strength) were omitted on obvious safety grounds. This left about 10 sites that fit all the constraints. These sites were then prioritized into two categories based on science rationale and safety considerations from a preliminary assessment of the Mars Digital Image Mosaic data base and surface hazard data (e.g., radar, thermal inertia). The first group includes two grab bag sites in outflow channels that debouch into Chryse and two highland sites (one with low-albedo eolian cover, one densely covered with a valley network). The second group consist of sites of large uniform material of essentially unknown composition. These sites include other highlands, ridged plains and young channel/lava sites. Unfortunately, no site provides both a grab bag of ancient Noachian material and dark eolian material.The top four sites were carefully evaluated using virtually all available data and models including: Viking images, therms] inertia, rock abundance, albedo, radar, color, occultation data, and weather data from Viking measurements and atmospheric models. (We gratefully acknowledge data and analyses by non-science team members P. Christianson, Arizona State University, M. Slade, JPL, and D. Smith and M. Zuber, Goddard Space Flight Center). All data were presented and discussed at the June 9-10, 1994 meeting of the Mars Pathfinder Project Science Group. Final selection was made by a democratic vote of all attending science team members.

The Pathfinder Landing Site selected is:

1) *Ares/Tiu Valles* (19.5°N, *32.8"W, -2* k m elevation) - This site is a grab bag site with the potential for sampling a variety of Noachian plateau material (aka, ancient crust) as well as Hesperian Ridged Plains and a variety of reworked materials. It is about as rocky as the Viking sites, but perhaps a bit less dusty. This site has clear streamlined islands nearby and a very smooth depositional surface at Viking resolution (order 30 m/pixel), except for large (hundreds of meters) blocks or hills. (Fig. 3)

Radar data will be collected of this site and other areas in this latitude band from the end of 1994 through early 1995. If the radar data show a surface considered dangerous for Pathfinder landing, the following alternate sites will be considered:

2) *Oxia Palus/Trouvelot Dark Highlands* (somewhere between 1O"N-17°N, 11 °W-20°W, and at ≤0 km elevation) - This is a site extracted from the desire expressed at the workshop to sample ancient highland crust and the desire to sample dark surficial/eolian deposits. The exact location of the landing ellipse is still being worked, but the attempt is to place the entire ellipse in dark eolian material that is below O km elevation, with reasonably high-resolution Viking images.

3) *Maja Vanes Fan (18.8"N,* 52°W, *-0.5* km elevation) - This site is also a grab bag site with similar sampling opportunities as site 1. A delta/fan is fairly clearly exposed at the location, although the landing ellipse can not be fit entirely on it. An ancient highland massif just above the fan could improve the likelihood of sampling ancient crustal material.

4) *Maja Highlands (* 13.5°N, 53°W, O km elevation) - This site was added because it would sample an ancient highlands region cut by a plethora of valley networks. Landing at this site would not only sample the highlands of Mars, general observations of the local area could help determine whether the valley networks resulted from rain or sapping, which has paleoclimatic implications. Overall the site appears fairly smooth at Viking resolution, except for a number of eroded craters. It is just to the south of the Maja fan/delta site.

Other potential Pathfinder landing sites that were eliminated during the selection process are listed below (in no particular order). All are large uniform sites of unknown composition (except for the Elysium lavas site, which is a large uniform site of known composition),

Dark Hesperian Ridged Plains (14"N, 243°W) - This site was added after the workshop to sample the important martian geologic unit known as ridged plains and dark eolian surface material, The site appears smooth in available Viking images, with few wrinkle ridges, giving it a very uncharacteristic appearance for ridged plains.

Marte Vallis (17°N, 176°W) - This area was suggested by a number of participants at the conference. At this location Pathfinder would sample either a young channel or young basalts. If it sampled channel material the sediments n the channel would be Hesperian and Amazonian in age.

Hypanis Valley Network (1 1.5”N, 45.5°W) -This site is sort of a hybrid, which includes a grab bag of the local highlands at the mouth of a highlands valley network channel system. Rocks are likely to be more locally derived than for a large outflow channel. The site is a fairly smooth depositional surface with some knobby terrain in the eastern part of the ellipse. Unfortunately, high resolution Viking imagery is not available for this site.

Isidis Planitia (15°N, 275°W) - This site was proposed at the workshop to sample late Hesperian plains sediments.

Tartarus Cones (1 1.5°N, 198”W) - This site samples both Hesperian/Noachian material and the dark eolian material. At the available Viking imagery coverage (moderate resolution only) the site appears very rough - a mass of knobs.

Elysium Lavas (13°N, 203°W) - This site was proposed to sample known Elysium lava flows. It is also in the dark eolian cover.

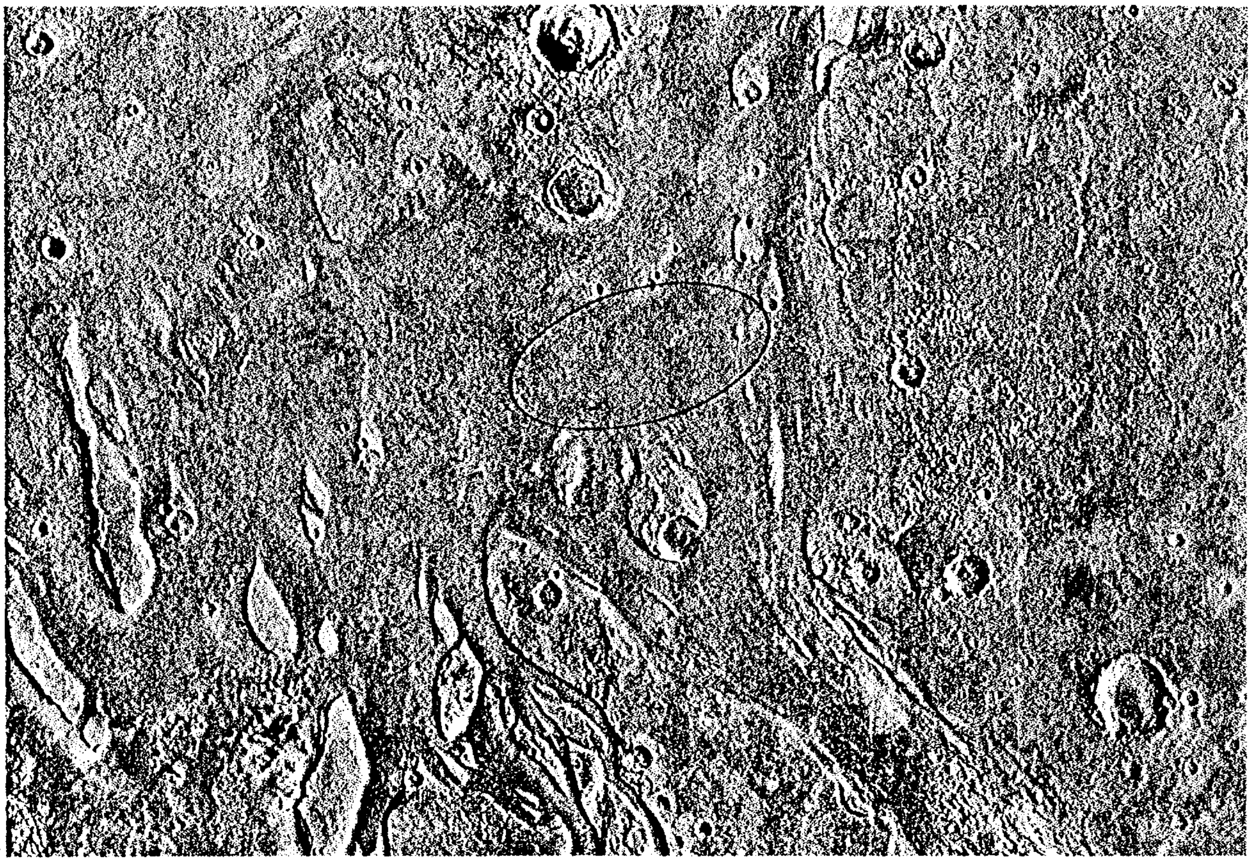

Fig 3. Regional mosaic showing the Mars Pathfinder landing site (100 km by 200 km landing ellipse shown: north is up). The mosaic shows the large catastrophic outflow channels debauching into Chryse Planitia. Ares Vallis flowed to the northwest (from the southeast) across the landing site. Tiu Vanes is just to the west of Ares Vallis and may also have flowed across the landing area. The channels formed from the catastrophic release of water from the martian subsurface and flow across the surface creating the channels formed from the martian subsurface and flow across the surface creating the channels and the characteristic large streamlined islands (just to the south and northeast of the landing ellipse). The landing site itself is a very smooth depositional surface, where the flood waters deposited the sediments carved from the channeling event. Landing at this location should allow the analyses of a wide variety “of rock types carried by the flood.

Summary

Mars Pathfinder, one of the first Discovery class missions, will place a lander, rover and several scientific instruments on the surface of the red planet in July 1997. The spacecraft is a single integrated vehicle consisting of a simple back-pack style cruise stage, a backcover and aeroshell of Viking heritage and a novel tetrahedron shaped lander. The spacecraft enters the martian atmosphere directly behind an aeroshell and slows itself on a parachute, small solid rockets and a number of airbags. The lander petals open, righting the vehicle and exposing solar panels for power. Three science instruments are included in the payload in addition to the rover and associated technology experiments, They are: a stereo imaging system on a pop up mast with a variety of spectral filters; an alpha proton x-ray spectrometer (mounted on the rover); and an atmospheric structure instrument/meteorology package.

The surface imaging system will reveal the geologic processes and surface-atmosphere interactions at a scale currently known only at the two Viking landing sites. The alpha proton x-ray spectrometer and the spectral filters on the imaging system will determine the elemental composition and mineralogy of rocks and surface materials, which can be used to address questions concerning the composition of the crust, its differentiation and the development of weathering products. A series of small magnets and a reference test chart will determine the magnetic component of the martian dust and any deposition of airborne dust over time. The atmospheric structure instrument will determine a pressure, temperature and density profile of the atmosphere (with respect to altitude) during entry and descent. Diurnal variations of the atmospheric boundary layer will be characterized by regular surface meteorology measurements (pressure, temperature, atmospheric opacity, and wind speed and direction). In addition, the imager will determine dust particle size and shape and water vapor abundance from sky and solar spectral observations.

A workshop was held to solicit ideas from the scientific community on where to land Pathfinder on Mars within the engineering constraints of being close to the sub-solar latitude (for maximum solar power) and below O km elevation (for parachute performance). The landing sites proposed at the workshop and the resulting discussion by the participants was used (o narrow down the sites chosen for intensive study, Four individual sites were selected for intensive study on the basis of the preferred attributes of sampling: 1) a wide variety of rock types deposited by an outflow channel; 2) ancient highlands; and 3) a dark surficial eolian unit. The Ares/Tiu Vanes outflow channel was chosen, located at 19.5°N, 32.8°W, and at -2 km elevation. This site offers the possibility of sampling a wide variety of ancient highlands crusts] units, as well as ridged plains and younger reworked materials.

References

(2) Golombek, M., ed. (1994) *Mars Pathfinder Landing Site Workshop.* LPI Technical Report 94-04, Lunar and Planetary Institute, Houston, XX pp, in press.